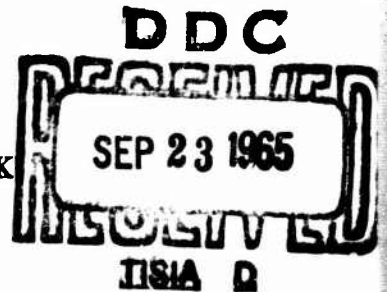


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DECISION INTERVAL AND SIGNAL  
DETECTABILITY IN A VIGILANCE TASKJANE F. MACKWORTH  
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## ABSTRACT

This paper discusses the effect of the assumed decision interval on the measurement of  $d'$ . Previous experiments have revealed a decrement in the detectability ( $d'$ ) of signals during a particular vigilance task involving the detection of a brief pause in the movement of a clock hand. In order to measure the false alarm probability, Ss were required to make a decision once every five sec. as to whether or not there had been a signal in the previous five sec. In this paper Ss were required to respond as soon as they saw a signal, and it was assumed that the decision interval was the signal duration. The thirty-fold change in assumed decision interval produced very little change in the decrement in  $d'$  during the run. It is therefore concluded that the length of the assumed decision interval was not a critical factor in determining changes in  $d'$  during the continuous clock task.

IT HAS BEEN REPORTED (Mackworth and Taylor, 1963) that in a particular vigilance task a decrement was observed in the detectability ( $d'$ ) of the signals during the course of the run. In this task the subject was required to detect brief pauses in the otherwise continuous movement of a clock hand. The clock face was divided into five-second intervals by white marks, and the subjects were told that there would never be more than one signal in any one five-second interval. Since the signals could occur at any moment within each five-second interval, the task effectively required continuous observation.

In the computation of  $d'$ , it is necessary to determine two parameters (Swets, Tanner, and Birdsall, 1961). These are the probability that the subject will claim to have detected a signal when one was in fact presented, and the probability that he will claim a detection when no signal was presented. When the task is divided into discrete intervals of time, each of which contains a single presentation either of a signal or of no signal, then computation presents no problem; the numbers of events "signal" and "no signal" are uniquely known. If the task is continuous, however, the number of events "no signal" is not known. Egan, Greenberg, and Schulman (1961) suggested one way of avoiding this problem; their method involved the assumption that the correct detection probability is a power function of the false alarm probability.

Mackworth and Taylor used a different approach. The subjects were told to respond only at the end of each five-second interval, when the

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clock hand passed a white mark. In this way the overt decision rate was limited to one decision every five seconds. In the computation of  $d'$  the false alarm probability was obtained by dividing the number of false positive reports by the number of five-second intervals that did not in fact contain a signal.

Since the signal was very short (0.2 second) compared with the overt decision interval of five seconds, it is doubtful whether the entire interval was treated as a unit by the subject when deciding whether or not a signal had been presented. An extreme alternative hypothesis is that the subject made a decision regarding the existence of the signal in each successive 0.2-second interval. According to this hypothesis, the signal would be reported only if some rather high criterion were exceeded in at least one of the 0.2-second intervals during the five-second period. If this was the case, the detectability levels computed on the assumption of 12 decisions per minute were much too low, since the estimated false alarm probabilities were too high by a factor of 25.

Two questions arise from these considerations. First, are the changes in detectability found by Mackworth and Taylor (1963) and also found in later experiments (Mackworth, 1964, 1965) dependent on the assumptions made in calculating the probabilities of false alarms, and secondly, would these changes in detectability be found if the subjects were allowed to respond as soon as they detected a signal?

In the present experiment, the detectability of the pause in the movement of the clock hand was varied in two ways. The marking on the clock face was varied, and the duration of the pause was changed. Suitable manipulation of these two variables can yield a constant detection probability with different signal durations; Mackworth (1963) showed that the presence of one or two white marks on the clock face substantially increased correct detections of pauses of a given length. In some conditions, discussed in the present paper, subjects were required to report only at the end of each five-second interval. In other conditions, they were free to report at any time. With free response, false alarms could conceivably be made as fast as the subject was able to respond, and decisions as fast as signals could be presented. Here the "natural" decision interval is the length of the signal, either 0.17 or 0.25 second. Values for  $d'$  were calculated using both the "natural" decision rate and a "transformed" decision rate in order to see what would happen to  $d'$  when these different methods of calculation were used.

#### METHOD

For the free-response situation, two clock faces were used. One was completely black, the other had a thin white mark at the top and another at the bottom. Groups

of seven housewives were tested simultaneously, each S sitting in an isolated booth in dim light and watching the image of the clock on a T.V. monitor. Group 1 was tested with the black clock face on two successive days. They were required to detect a signal consisting of a pause of 0.25 sec. duration in the movement of the clock hand. Group 2 was tested with the clock face showing two white marks and was required to detect a signal of 0.17 sec. duration. These signal lengths were chosen to give approximately the same probability of detection.

The Ss were given a practice run of ten signals in approximately three min., during which a red light was used to indicate to S that she had missed a signal. All Ss detected at least half the signals in this practice period. Immediately after this practice they were told that the main run would begin, and auditory noise of 68 db was introduced into each booth to obscure external noises. There were 180 signals in the hour's run with 15 signals in each five-min. period. The interval between signals varied from 10 to 30 sec. The Ss were instructed to respond as soon as they saw a signal, and they were encouraged to make a response if they were doubtful as to whether a signal had occurred.

Responses were recorded on an Esterline-Angus 20-pen recorder, and any response within two sec. after presentation of a signal was scored as a correct response. Hence there was an average of 54 sec. per minute during which responses were incorrect. Since there were few false alarms there was seldom any doubt as to whether or not a response was correct.

### RESULTS

Table I shows the percentage of correct detections and the percentage of false alarms for Groups 1 and 2. These were calculated on the assumption that a decision was made every 0.25 second by the subjects of

TABLE I  
PERCENTAGE OF SIGNALS DETECTED AND OF FALSE ALARMS, WITH FREE AND RESTRICTED RESPONSES, AND CLOCK FACES WITH DIFFERENT NUMBERS OF MARKS

Period (min.)	% Detection				% False alarms			
	Group 1	2	3	4	Group 1	2	3	4
	Marks 0	2	12	12	Marks 0	2	12	12
0-10	72	76	79	70	0.18	0.3	4.8	1.4
10-20	63	69	69	59	.13	.4	4.0	1.2
20-30	57	69	62	45	.11	.4	3.7	0.8
30-40	56	62	59	46	.14	.5	3.8	1.9
40-50	56	59		42	.26	.4		1.0
50-60	59	58		44	.16	.5		1.4

Groups 1 and 2, free response.

Groups 3 and 4, maximum 12 responses/min.

Signal duration, Group 1: 0.25 sec.; Groups 2, 3, 4: 0.17 sec.

Group 1, and every 0.17 second by those in Group 2. It can be seen that Group 2 gave many more false alarms than Group 1, and also that there was no consistent change in false alarm rate during the run.

## DISCUSSION

Table I also shows data from control groups (3 and 4) used in other experiments (Mackworth, 1963a, and unpublished data). These subjects were tested with a clock showing twelve white marks and were instructed to respond only when the clock hand passed the white mark which ended the five-second interval in which they had seen a signal. The signal duration for these subjects was 0.17 sec. The decision interval was assumed to be 5 seconds, and since there were 180 signals an hour, as for Groups 1 and 2, in each minute there was an average of nine decision intervals which did not contain signals.

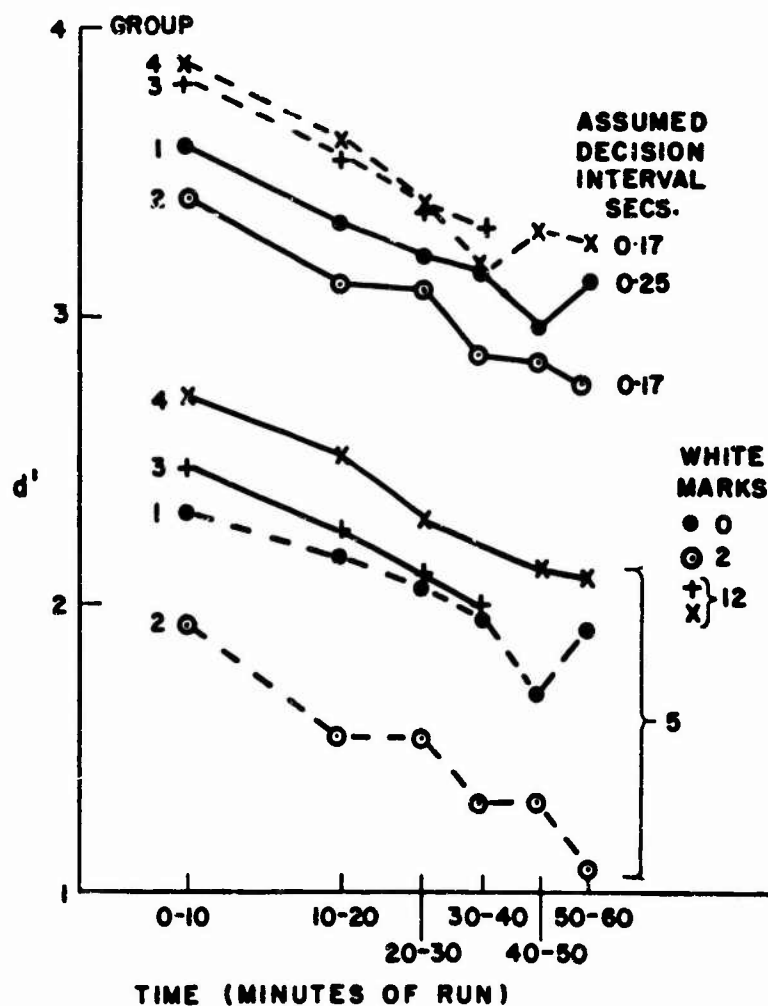


FIGURE 1

Figure 1 shows values for  $d'$  obtained from tables (Elliott, 1964). The curves drawn with solid lines represent the values for  $d'$  obtained from the false alarm percentages shown in Table I. These values have been plotted against the time on task shown on a square root scale. This scale has been found appropriate for a wide variety of tasks involving continuous observation (Mackworth, 1964b).

It can be seen that the different methods of limiting responses and calculating the decision rate have a considerable effect on the absolute values of  $d'$ , but very little effect on the rate at which  $d'$  decreases during the run. It is probable that the two decision intervals which have been employed represent two extreme assumptions. Egan, *et al.* (1961) demonstrated with the method of free response that nearly all responses to actual signals occurred within one second, though the onset of response was displaced slightly with different criterial levels. By two seconds after the signal, the responding rate had returned to the base line that represented the false alarm rate. Thus it is probable that the "true" decision interval lies somewhere between the two extremes used here.

Figure 1 also shows what happens to  $d'$  when the assumptions about the decision rate are changed, without changing the actual experimental conditions. The results from Groups 1 and 2 (free response) were recalculated on the basis of a decision interval of five seconds. This is a purely theoretical calculation, since it is unlikely that subjects actually operated at such a slow rate when there was no indication to them that they should. The results of the calculations are shown in the lower broken lines in Figure 1. For Group 1, there was a decrease of 0.4 unit of  $d'$  from the first to the last ten minutes of the run, and this decrease is the same whether the calculation is made on the basis of a decision interval of 0.17 second or of five seconds. Group 2 shows an increased decrement in  $d'$  during the run with the longer decision interval. There was a decrease of 0.65 unit of  $d'$  when measured with the decision interval of 0.17 second and a decrease of 0.86 unit during the run when calculated with an assumed decision interval of five seconds. This group had an unusually high false alarm rate. The false alarm percentage for the last ten minutes of the run was 19 per cent, when the five-second decision interval was used as a basis for calculation. In other words, two false alarms were quite likely to occur within one five-second period. Even so, the decrement in  $d'$  from the first to the fifth ten minutes of the run only shows a 10 per cent difference with the two methods of calculation.

A similar transformation has been made with Groups 3 and 4. When the decision interval is taken as the signal duration, that is 0.17 second, the values of  $d'$  obtained are shown by the upper broken lines. Again the transformation causes very little change in the difference between

the first and last ten minutes of the run. Group 3 shows a change from 0.46 to 0.51 unit of  $d'$ , and Group 4 shows a change from 0.68 to 0.59 unit, when the assumed decision interval is decreased to 0.17 second.

There are some changes in the relative positions of the curves when the assumed decision interval is changed. One reason for this is that the large differences in false alarm rates result in sampling different parts of the probability curves used for the calculation of  $d'$ . The only curves that show an actual reversal of relative levels are those for Groups 3 and 4. These two groups received the same experimental conditions. Group 2 received the same signal as Groups 3 and 4, but was shown two white marks on the clock as opposed to twelve for Groups 3 and 4. This difference in display was expected to make a difference in detectability.

It can be concluded that the assumed decision interval can be widely varied with a thirty-fold change, with little effect on the decrement in  $d'$  during a run. Nor does it seem to make much difference to the rate of decrement whether the subject is restricted to twelve responses per minutes or allowed to respond freely. It therefore follows that the changes in  $d'$  described in the various papers mentioned above are not dependent on possible artifacts introduced by the assumed decision interval.

#### RÉSUMÉ

Effet produit par l'intervalle hypothétique de décision sur la mesure de  $d'$ . Des expériences antérieures ont montré une diminution de la repérabilité ( $d'$ ) des signaux pendant une tâche particulière d'attention impliquant le repérage d'un arrêt bref au cours du mouvement d'une aiguille chronométrique. Pour qu'il soit possible de mesurer la probabilité de fausses alertes, les sujets étaient obligés de décider une fois par cinq secondes s'il s'était produit ou non un signal pendant les cinq secondes écoulées. Dans l'étude ici rapportée, les sujets doivent répondre dès qu'ils voient un signal et l'on assume que l'intervalle de décision est la durée du signal. La modification (à 30 niveaux) de l'intervalle hypothétique de décision a très peu d'effet sur la diminution de  $d'$  au cours de la série. On peut donc en conclure que la longueur de l'intervalle hypothétique de décision n'est pas un facteur crucial dans la modification de  $d'$  pendant la tâche considérée.

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